



# **The **O**rbiting **C**arbon **O**bservatory-2 (**OCO-2**) Mission**

*Watching The Earth Breathe... Mapping CO<sub>2</sub> From Space.*

## **A54G-07: Latest on Validation of OCO-2 XCO<sub>2</sub> Observations and an Update on the Upcoming Reprocessing**

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- (1) Jet Propulsion Laboratory, Pasadena, CA
- (2) California Institute of Technology, Pasadena, CA,
- (3) Colorado State University, Fort Collins, CO

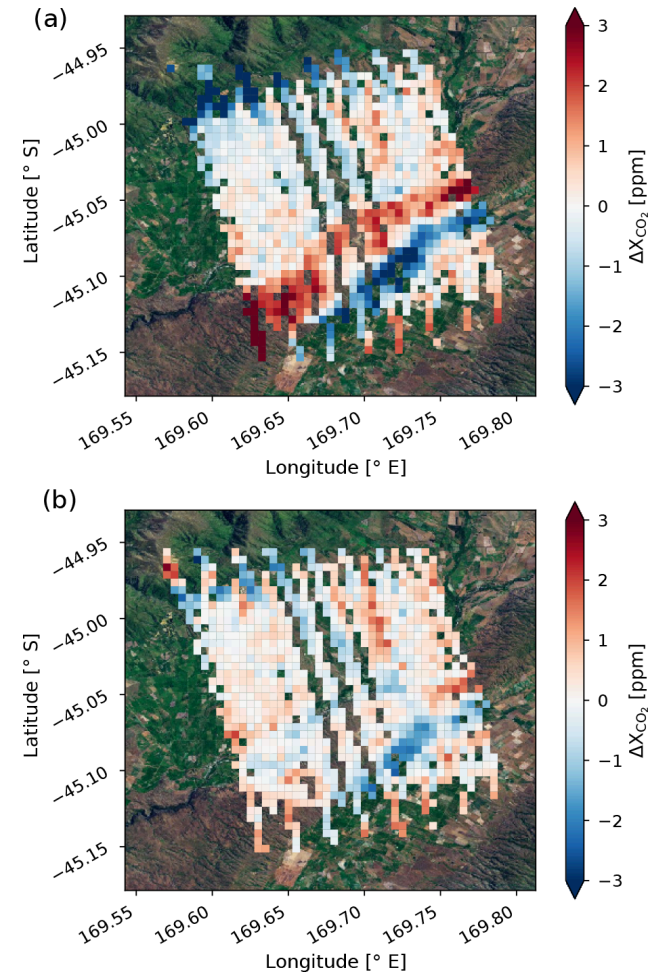
**AGU  
100 | FALL MEETING**



# OCO-2 L2 Data Product

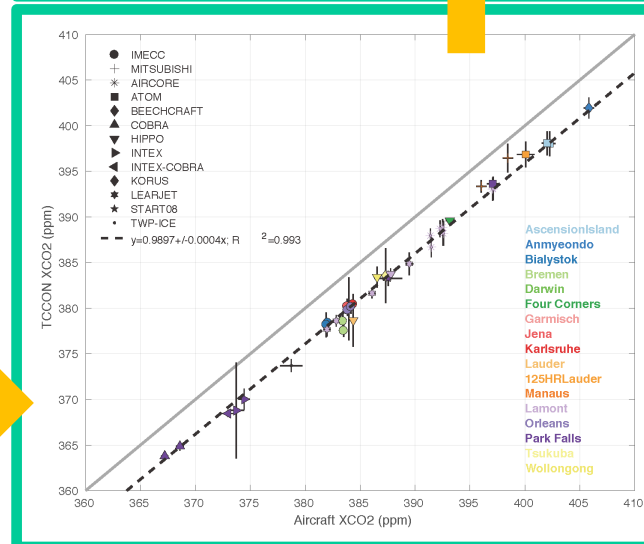
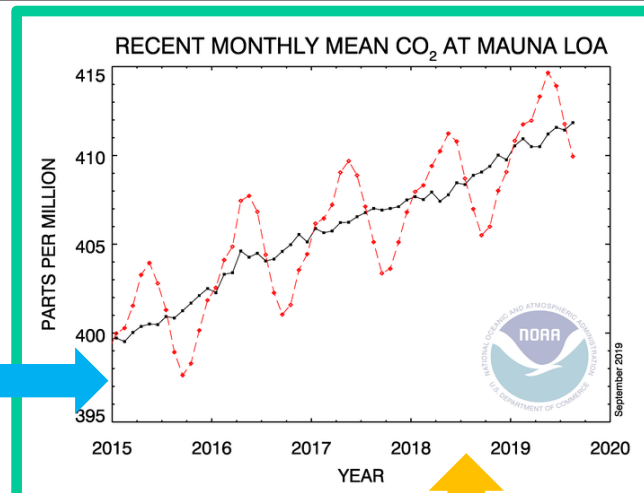
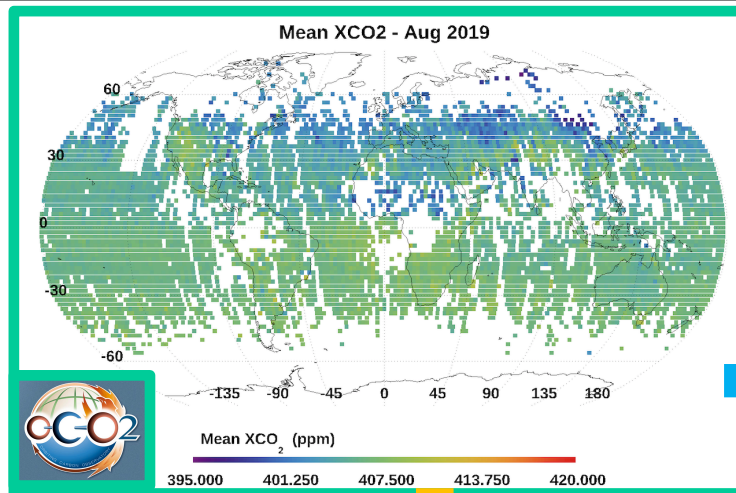
- OCO-2 v09 is the current release of the Level 2 XCO<sub>2</sub> data product (since July 2018).
- A systematic pointing error was noticed in v08 target observations with variations in topography within the scene (Lauder, Pasadena)
- OCO-2 v09 is built off v08 L1B data but addresses a pointing correction and an issue in the sampling of the meteorological data in retrievals.
- Available at the Goddard Earth Sciences Data and Information Services Center (*GES DISC*)
  - XCO<sub>2</sub> Lite File Data Product:  
[https://disc.gsfc.nasa.gov/datasets/OCO2\\_L2\\_Lite\\_FP\\_9r/summary?keywords=OCO-2](https://disc.gsfc.nasa.gov/datasets/OCO2_L2_Lite_FP_9r/summary?keywords=OCO-2)
  - SIF Lite File Data Product:  
[https://disc.gsfc.nasa.gov/datasets/OCO2\\_L2\\_Lite\\_SIF\\_8r/summary?keywords=OCO-2](https://disc.gsfc.nasa.gov/datasets/OCO2_L2_Lite_SIF_8r/summary?keywords=OCO-2)

Kiel et al., *Atmos. Meas. Tech.*, **12**, 2241–2259, 2019.



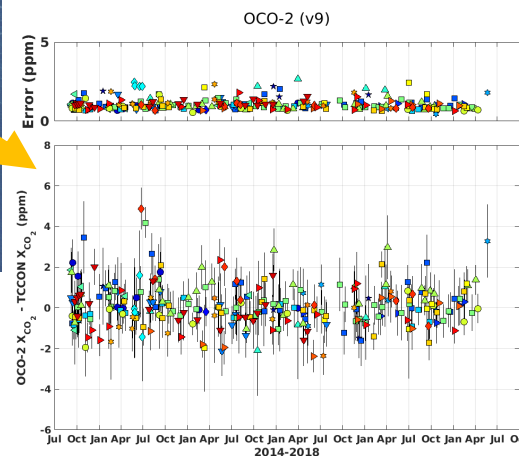
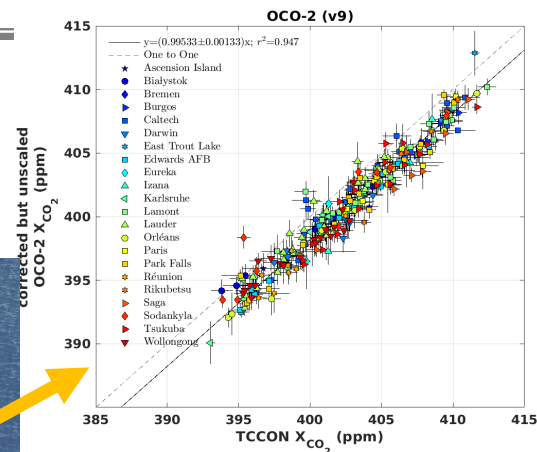
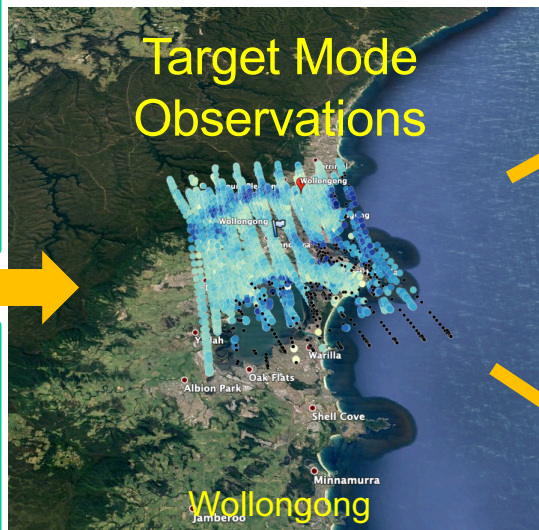
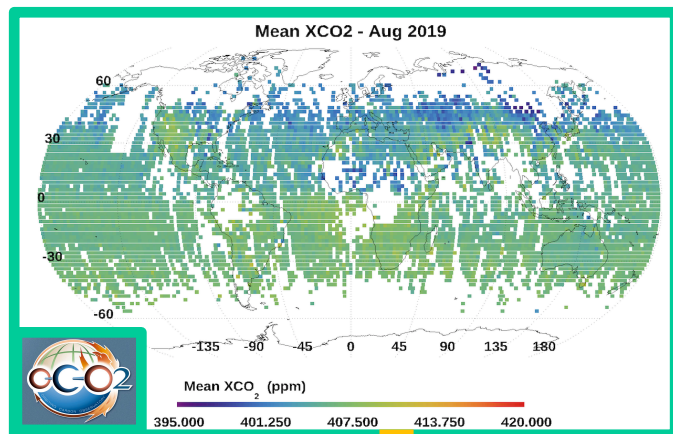
OCO-2 target observation of Lauder, NZ

# OCO-2 Validation Plan





# OCO-2 Validation: Target Mode

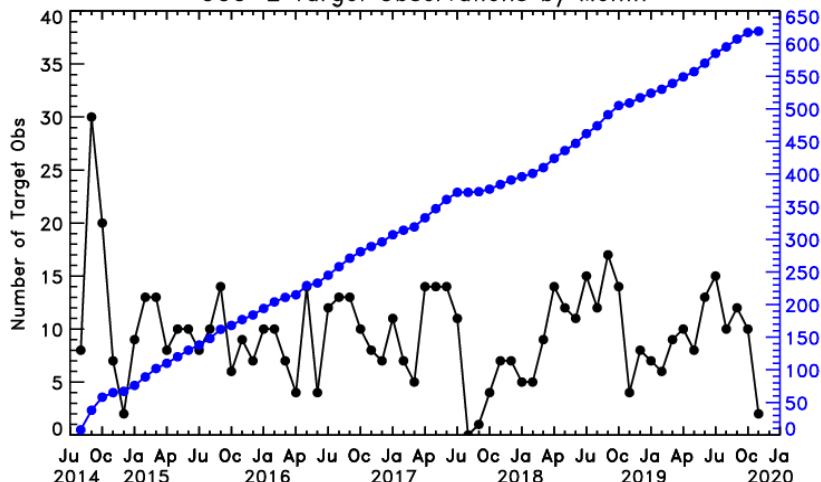


TCCON Partners have provided early access to preliminary data for OCO-2 target observations throughout the mission – [Thank you!](#)

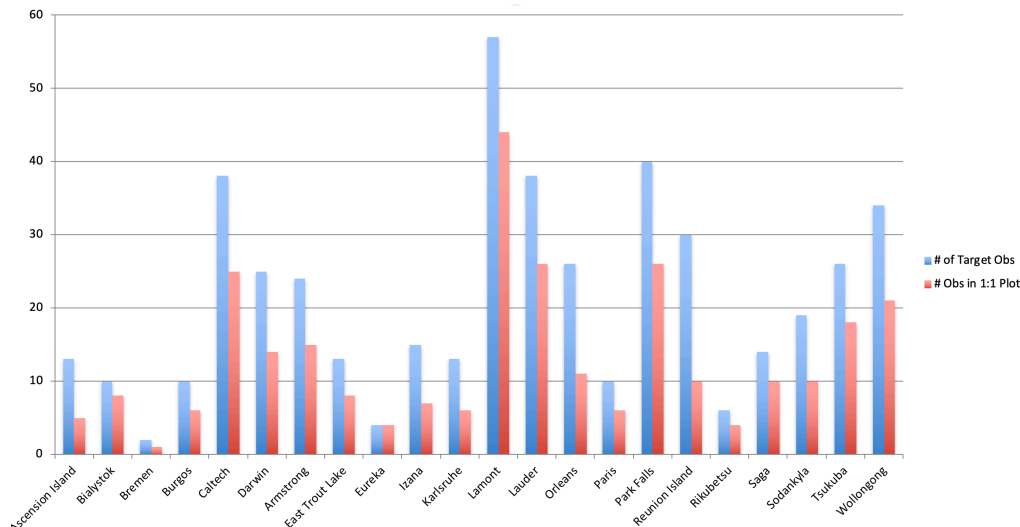


# OCO-2 Target Observation Statistics

OCO-2 Target Observations by Month

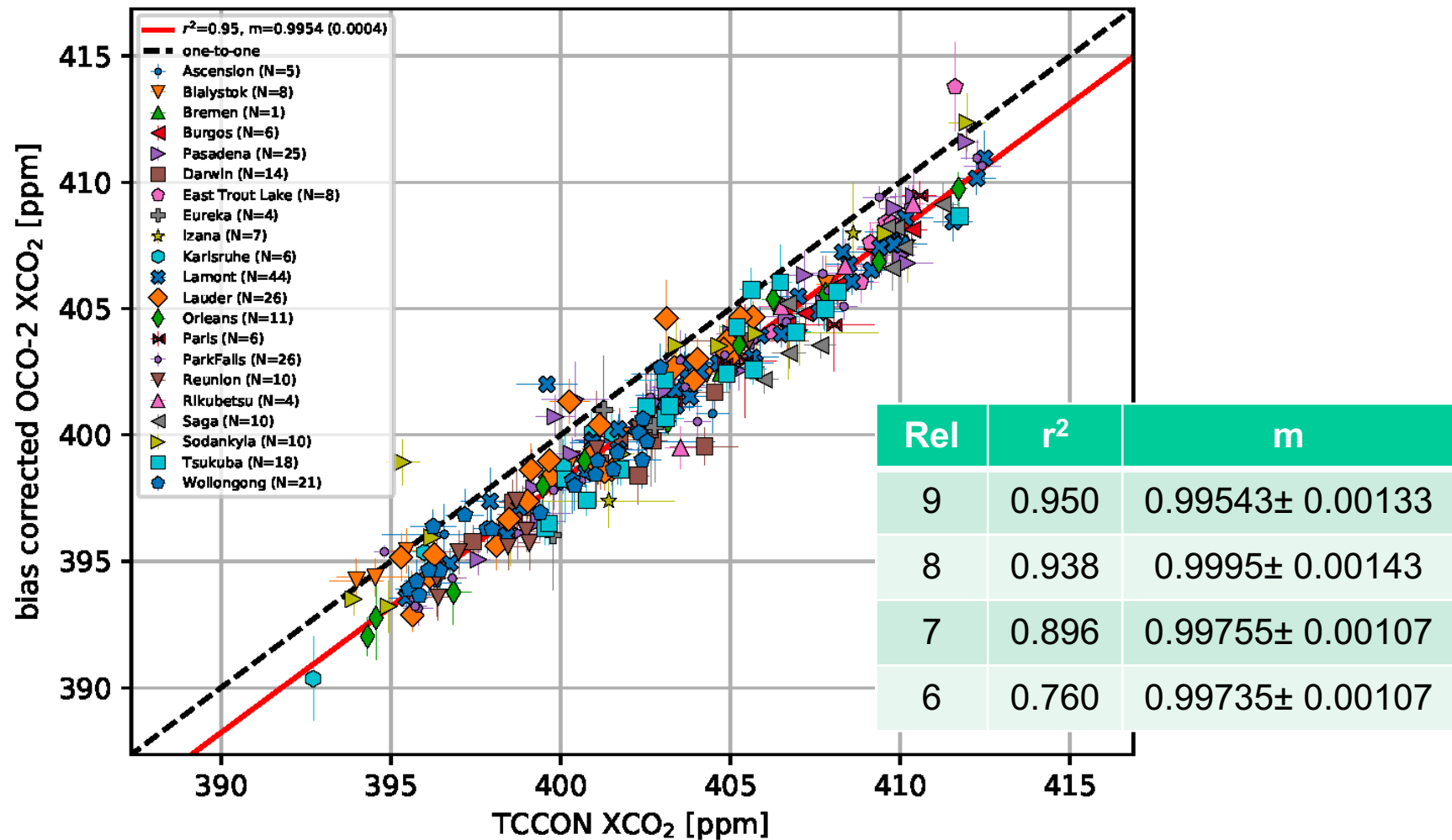


- OCO-2 has executed 625 target observations since August 8, 2014
- Usually get 8-12 per month
- Try to get Lamont, Railroad Valley at least once per month

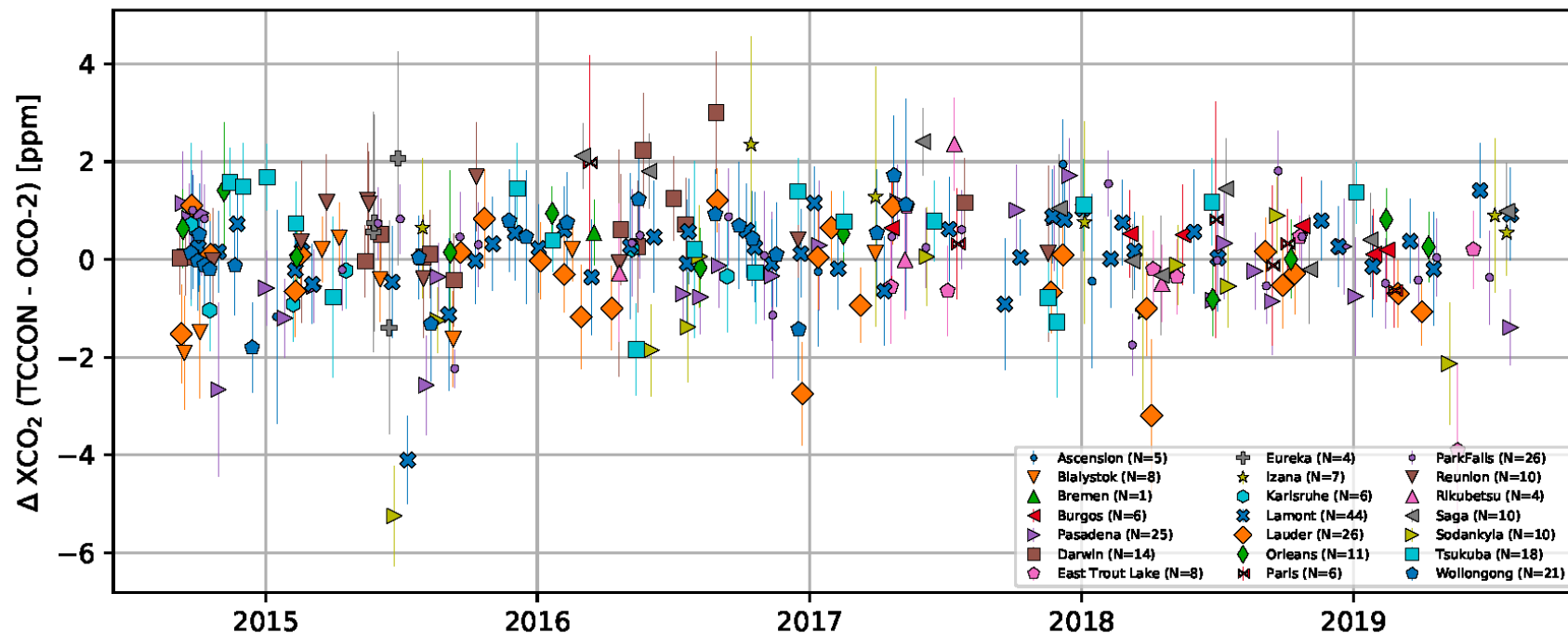


- Targets observed by TCCON site (blue)
- Targets used in OCO-2 vs TCCON 1:1 plot (pink)

# TCCON vs OCO-2: OCO-2 V9 Data



# Comparisons with TCCON Consistent in Time

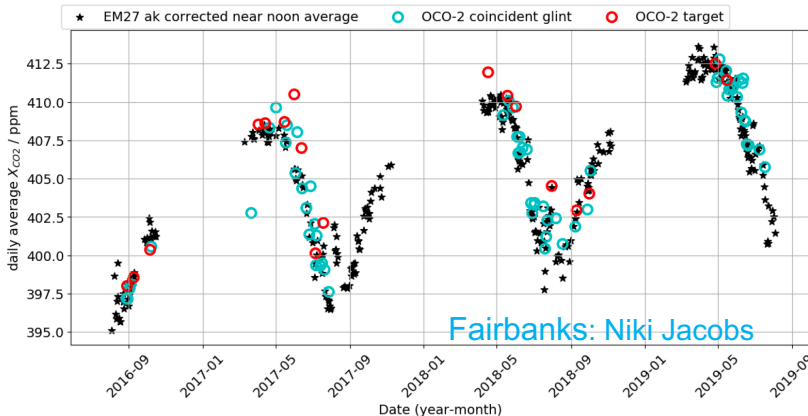




# EM27 Spectrometers

- Smaller version of the spectrometer used at TCCON sites
- Portable, easily deployed and moved
- Did not exist when OCO-2 validation plan was first developed.
- One target location dedicated to EM-27 observations (Fairbanks)
- Networks in Toronto, Munich, Massachusetts (possible future OCO-2 targets)

$X_{CO_2}$  from satellite and ground observations in Alaska, B9 QC and bias correction



- ▶ Poker Flat: 3 successful targets
- ▶ UAF: at least 15 successful targets

- ▶ OCO-2 measurements are the daily averages of coincident B9 soundings (within a 5° latitude by 10° longitude region) with `xco2_quality_flag = 0`.

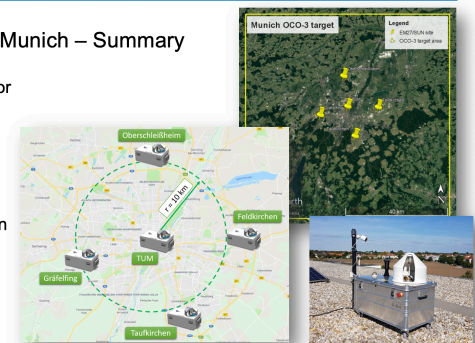


Professorship of Environmental Sensing and Modeling  
TUM Department of Electrical and Computer Engineering  
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TUM

## EM27/SUN observations in Munich – Summary

- Permanent ground-based sensor network in Munich
- 5 fully-automated stations
- Measured gas species:  $CO_2$ ,  $CH_4$ , CO
- Suited for target mode validation

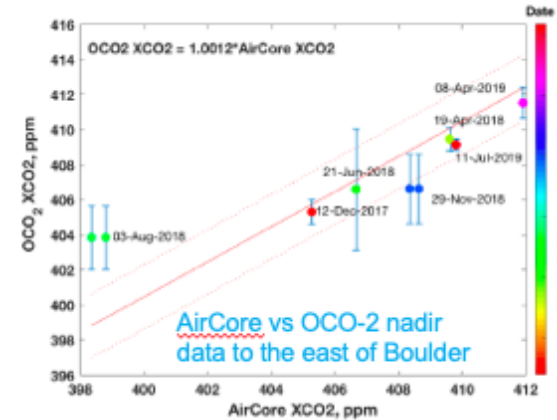
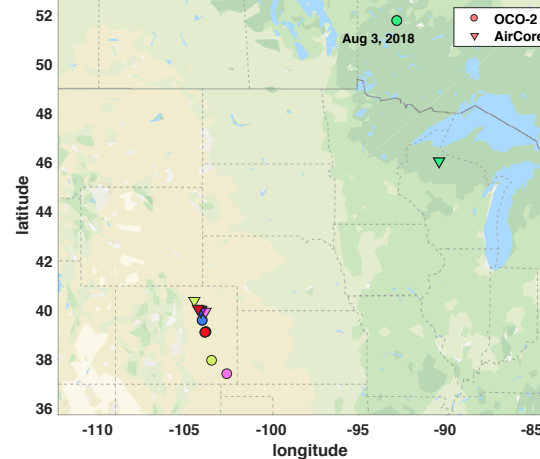


Munich: Jia Chen

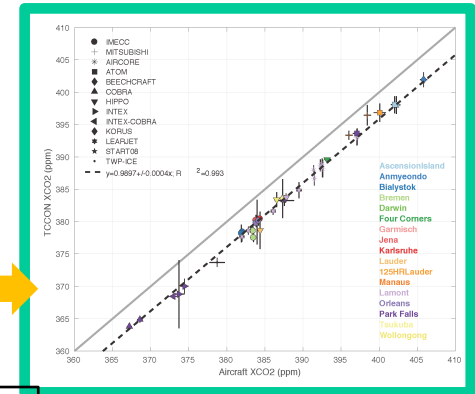
Jia Chen, Florian Dietrich | EM27/SUN observations in Munich

# AirCore Contributions to TCCON, OCO-2 Calibration/Validation

- Balloon-based platform provides CO<sub>2</sub> profile measurements well into the stratosphere
- Provides “calibration” for TCCON and validates the OCO-2/TCCON a priori profiles of CO<sub>2</sub>



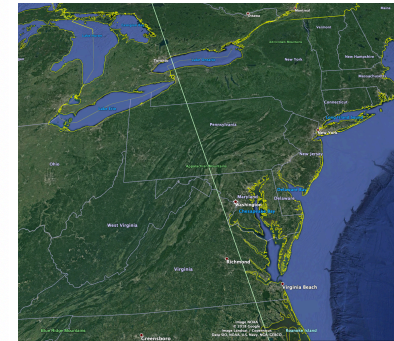
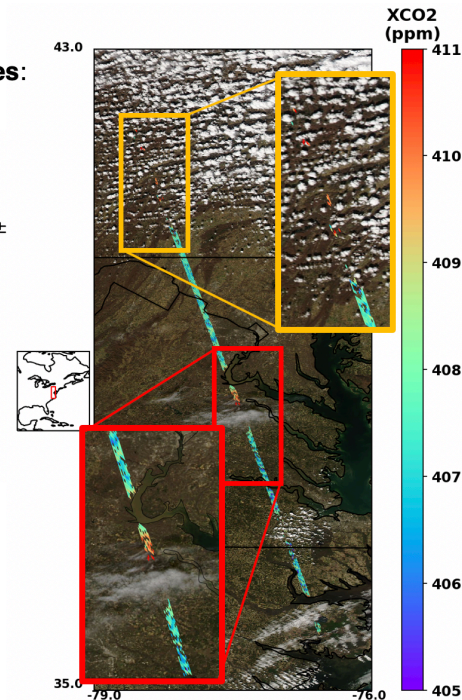
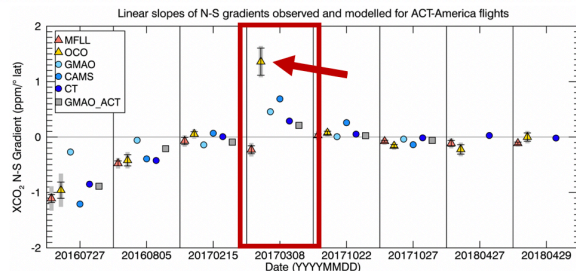
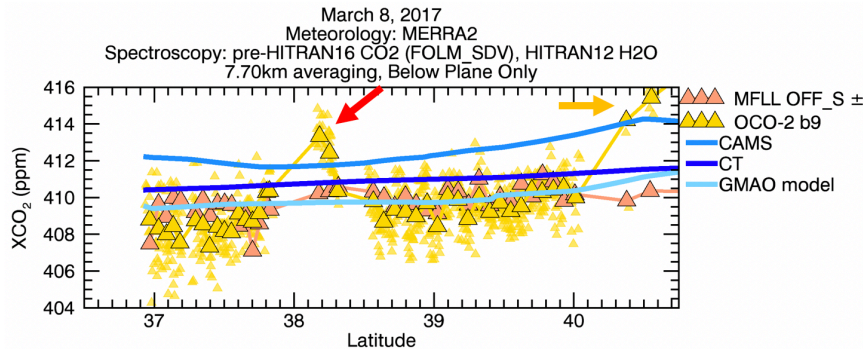
Colorado AirCore launches since Dec. 2017 coincident with OCO-2 overpasses.



**AirCore: Bianca Baier (NOAA)**

# NASA ACT-America Campaign: Aircraft Observations of CO<sub>2</sub>

MFL vs. OCO-2 Agreement – Paper updates:  
March 8, 2017 Investigation



OCO-2 Predicts

- Flight planners used predictions of OCO-2 ground track
- Comparisons of OCO-2 to lidar measurements
- Observations under different cloud conditions – shows impact of cloud effects on retrievals
- Analysis by Emily Bell, Colorado St University – Paper in preparation

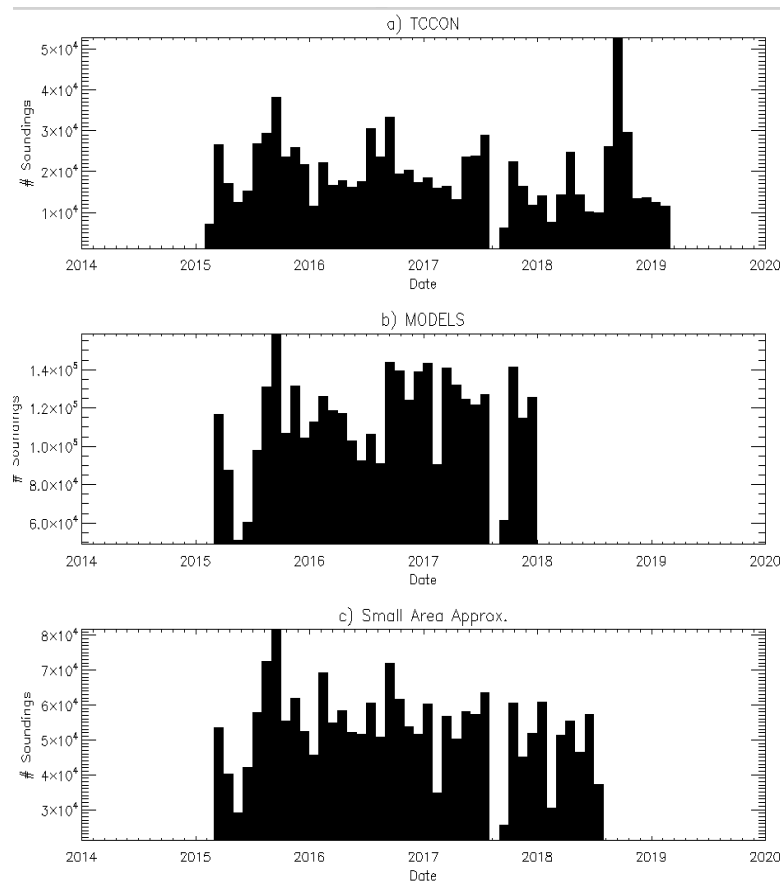
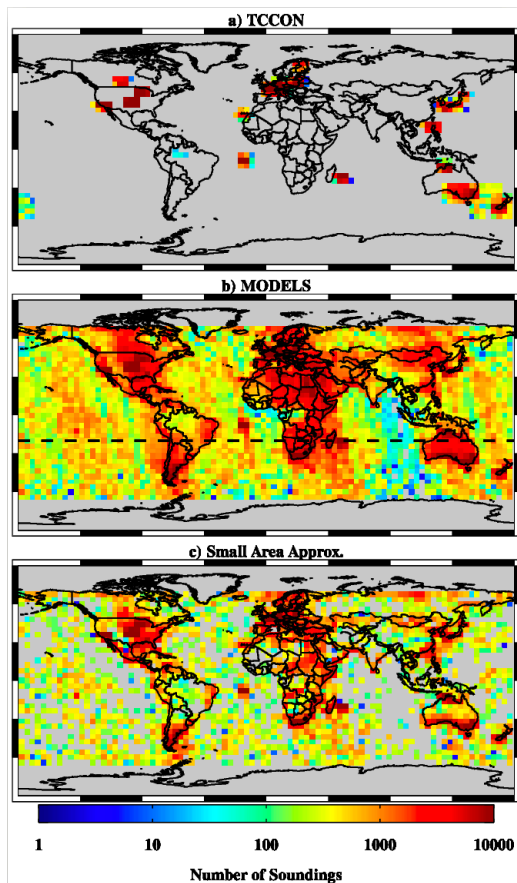


# OCO-2 V10 Data Product

- Development and testing of the OCO-2 v10 retrieval products
- Updates in V10:
  - Updated calibration of L1B data
  - Improved solar continuum model
  - Improved Spectroscopy – ABSCO 5.1
  - New a priori for CO<sub>2</sub> – Developed by TCCON team at Caltech, OCO-2 and TCCON a priori values for CO<sub>2</sub> will be consistent
  - Changes to how albedo over land is handled in the retrieval
  - Loosened a priori for the SIF retrievals over land
- V10 data product will be available in late 2020:
  - November – December 2019: Processing of one year of data for further evaluation
  - January – February 2020: Finalize filtering and bias correction for Lite files
  - ~September 2020: Full OCO-2 data record processed with Lite files

# Validation/Evaluation of V10 Prototype Data

Test set of data that allowed comparison to TCCON, models and using small area analysis was developed



# Validation/Evaluation of V10 Prototype Data: OCO-2 Land Nadir/Glint vs TCCON

Checking errors with each update to the retrieval

		<u>Ntot</u>	% Pass	Sigma(single)	Sigma(averaged)
V09	B9 (v10-baseline)	460K	63.5%	1.20 ppm	1.05 ppm
	Baseline2	464K	62.4%	1.20 ppm	1.05 ppm
	CO2-Scale	460k	63.8%	1.50 ppm	1.23 ppm
	O2-absco-scaling	462k	62.0%	1.20 ppm	1.05 ppm
	Fixed <u>Psurf</u>	448k	65%	1.24 ppm	1.14 ppm
	SIF-sigma-scale	463k	62.1%	1.18 ppm	1.03 ppm
	Baseline3	462k	63.4%	1.19 ppm	1.02 ppm
	Quadratic-Albedo	462k	67.4%	1.14ppm	1.01 ppm
	CO2-Band-Offsets	462k	65.1%	1.22 ppm	0.99 ppm
	New Co2 Prior	455k	63.3%	1.19 ppm	1.02 ppm
	Baseline4	455k	67.7%	1.08 ppm	0.97 ppm
	Baseline5	461k	66.8%	1.07 ppm	0.97 ppm
V10	Baseline6	461k	69.0%	1.06 ppm	0.96 ppm



# Validation/Evaluation of V10 Prototype Data: OCO-2 Land Nadir/Glint vs TCCON

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V09	B9 (v10-baseline)	460K	63.5%	1.20 ppm	1.05 ppm
	Baseline2	464K	62.4%	1.20 ppm	1.05 ppm
	CO2-Scale	460k	63.8%	1.50 ppm	1.23 ppm
	O2-absco-scaling	462k	62.0%	1.20 ppm	1.05 ppm
	Fixed <u>Psurf</u>	448k	65%	1.24 ppm	1.14 ppm
	SIF-sigma-scale	463k	62.1%	1.18 ppm	1.03 ppm
	Baseline3	462k	63.4%	1.19 ppm	1.02 ppm
	Quadratic-Albedo	462k	67.4%	1.14ppm	1.01 ppm
	CO2-Band-Offsets	462k	65.1%	1.22 ppm	0.99 ppm
	New Co2 Prior	455k	63.3%	1.19 ppm	1.02 ppm
	Baseline4	455k	67.7%	1.08 ppm	0.97 ppm
	Baseline5	461k	66.8%	1.07 ppm	0.97 ppm
V10	Baseline6	461k	69.0%	1.06 ppm	0.96 ppm

# Validation/Evaluation of V10 Prototype Data: OCO-2 Ocean Glint vs TCCON

Checking errors with each update to the retrieval

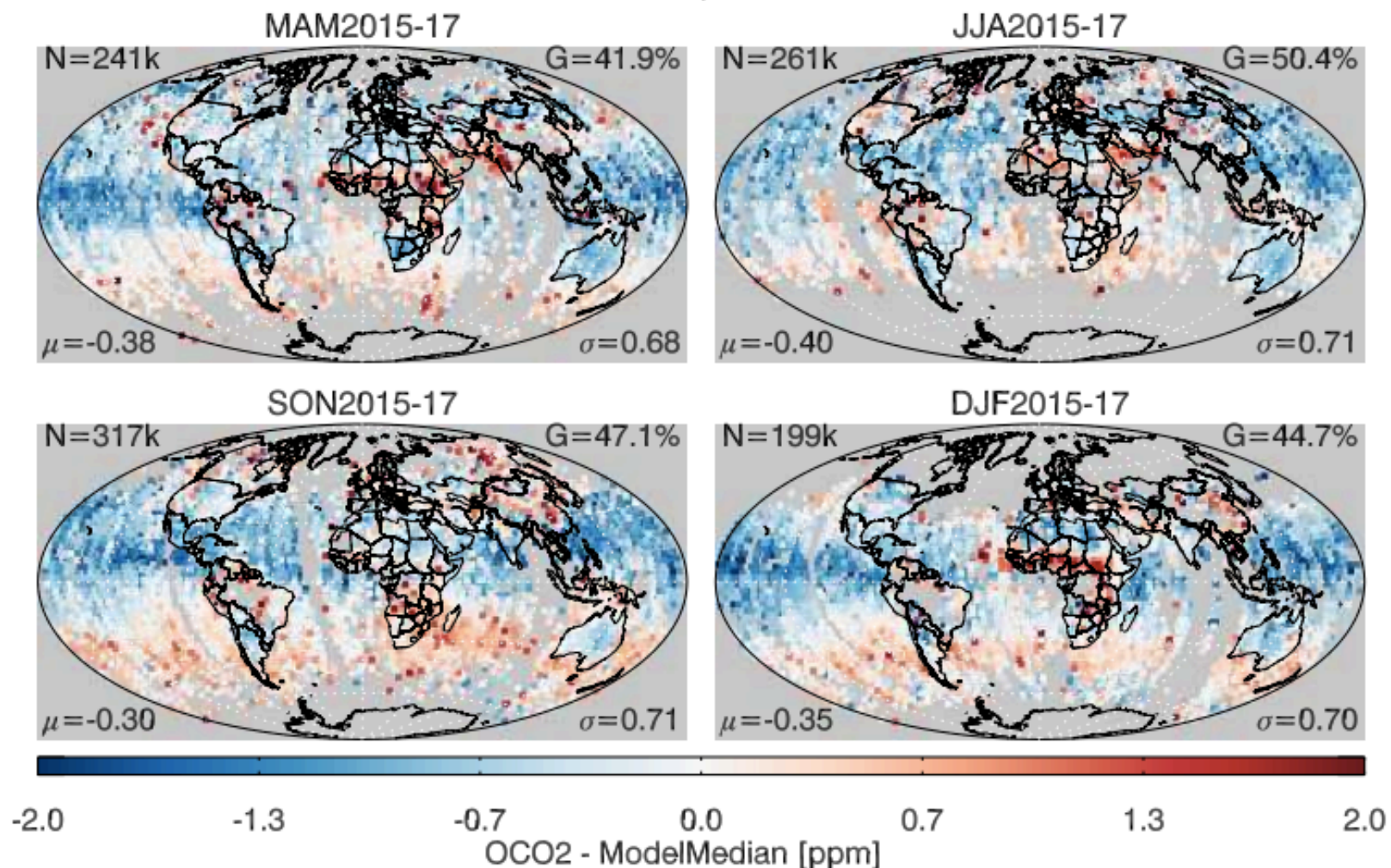
		<u>Ntot</u>	% Pass	<u>Sigma(single)</u>	<u>Sigma(averaged)</u>
V09	B9 (v10-baseline)	172k	68.9%	0.86 ppm	0.82 ppm
	Baseline2	175k	69.5%	0.82 ppm	0.77 ppm
	CO2-Scale	173k	60.1%	0.99 ppm	0.96 ppm
	O2-absco-scaling	174k	67.7%	0.80 ppm	0.76 ppm
	Fixed <u>Psurf</u>	171k	69.3%	0.81 ppm	0.77 ppm
	Baseline3	174k	69.8%	0.81 ppm	0.76 ppm
	CO2-Band-Offsets	173k	71.3%	0.85 ppm	0.77 ppm
	New CO2 Prior	171k	69.2%	0.80 ppm	0.75 ppm
	Baseline4	171k	69.4%	0.79 ppm	0.74 ppm
	Baseline4:newBC	171k	69.4%	0.76ppm	0.70 ppm
V10	Baseline5	173k	70.8%	0.80 ppm	0.74 ppm
	Baseline6	173k	71.6%	0.79 ppm	0.72 ppm

# Validation/Evaluation of V10 Prototype Data: OCO-2 Land Nadir/Glint vs TCCON

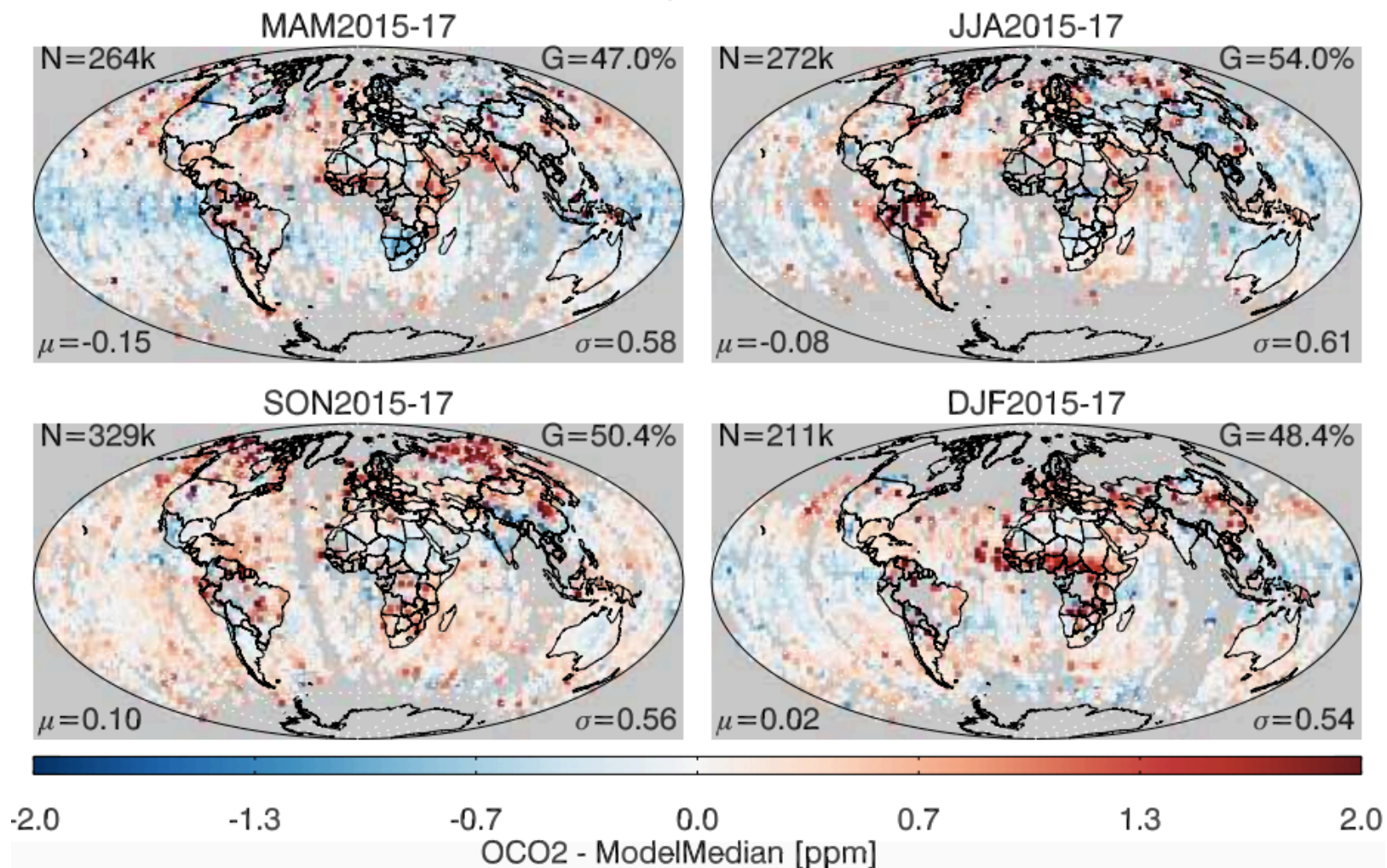
Checking errors with each update to the retrieval					
	Ntot	% Pass	Sigma(single)	Sigma(averaged)	
V09	B9 (v10-baseline)	1520K	45.6%	1.12 ppm	0.90 ppm
	Baseline2	1196K	45.2%	1.15 ppm	0.93 ppm
	CO2-Scale	1178k	46.4%	1.51ppm	1.19 ppm
	O2-absco-scaling	1191k	44.8%	1.16ppm	0.935 ppm
	Fixed Psurf	1106k	48.4%	1.19 ppm	0.97 ppm
	SIF-Sigma-Scale				
	Baseline3	1193k	45.6%	1.15 ppm	0.91 ppm
	Quadratic-Albedo	1200k	47.5%	1.08 ppm	0.88 ppm
	CO2-band-offsets	1196k	46.7%	1.10ppm	0.84 ppm
	New CO2-Prior	1172k	45.5%	1.15 ppm	0.92 ppm
	Baseline4	1178k	48.1%	0.99 ppm	0.82 ppm
	Baseline5	1297k	48.0%	0.99 ppm	0.81 ppm
V10	Baseline6	1296k	49.9%	1.00 ppm	0.82 ppm
	Baseline7	1297k	48.3%	1.06 ppm	0.86 ppm



## Differences vs. Model Median: B9



# Differences vs. Model Median: B10



# Summary

- OCO-2 target observations comparison to TCCON are essential to maintain the validation record
- EM-27 are already playing a growing role in OCO-2 validation and will play a more important role in the future (e.g., information on variability within an OCO-2 target)
  - Useful also for cross validation with OCO-3 and research studies
- AirCore (balloon) profile measurements are providing calibration/validation data for TCCON as well as directly to OCO-2
- Aircraft data coincident with OCO-2 observations are providing insight into cloud effects and CO<sub>2</sub> profiles
- V10 OCO-2 data will be available summer 2020: Test sets being evaluated using TCCON and models